

IN THE CLAIMS:

Please amend the claims as follows:

Claim 1[[,]], (currently amended) A method for the characteristics of the rate distortion optimization (RDO) based rate control scheme include comprising:

Step 1: Does performing bit allocation for every picture in a GOP which includes an I frame, a P frame, or a B frame, and based on the allocated bits a predicted quantization parameter being is used to do a first rate distortion optimization mode selection for every macroblock in the current picture[[:]], wherein the predicted quantization parameter is the quantization parameter of a previous macroblock, and a coding mode minimizing the following formula is selected as the initial coding mode for the current macroblock;

$$D(s, c, MODE | QP) + \lambda_{MODE} R(s, c, MODE | QP)$$

wherein s is the luma value of the original macroblock, c is the luma value of the reconstructed macroblock, λ_{MODE} is the lagrangian constant;

$$\text{for I/P frame, } \lambda_{MODE} = 0.85 \times 2^{\frac{qp-1}{3}};$$

$$\text{for B frame, } \lambda_{MODE} = 4 \times 0.85 \times 2^{\frac{qp-1}{3}};$$

$D(s, c, MODE | QP)$ is used to evaluate the distortion of the current macroblock after it is coded with mode $MODE$;

$R(s, c, MODE | QP)$ is the bits used to code the macroblock with mode $MODE$;

QP is a quantization parameter for the current macroblock, and is equal to the predicted quantization parameter in the first rate distortion mode selection;

Step 2: The the information collected from the first rate distortion mode selection being is used to calculate a final quantization parameter for rate control, and if the final quantization parameter is different from the predicted, a second rate distortion mode selection will be executed again.

Claim 2[[,]], (currently amended) The method of as claim 1 has said, wherein in step 1, before coding a GOP, does bit allocation for the pictures in the GOP with the average picture size is performed[[:]].

Claim 3[[,]], (currently amended) The method of as claim 2 has said, wherein the average

picture size is calculated as:

$R/F = R \div F$, here, R is the target bit rate. F is the picture rate. R/F is the average picture size.

Claim 4[.], (currently amended) The method of as claim 1 and claim 2 have said, further comprising performing does bit allocation adjustment in the coded GOP[.], wherein the adjustment is implemented as follows:

$$T_i = \max \left\{ \frac{R}{1 + \frac{N_p X_p}{K_p X_i} + \frac{N_b X_b}{K_b X_i}}, \frac{bit_rate}{8 \times picture_rate} \right\}$$

$$T_p = \max \left\{ \frac{R}{N_p + \frac{N_b K_p X_b}{K_b X_p}}, \frac{bit_rate}{8 \times picture_rate} \right\}$$

$$T_b = \max \left\{ \frac{R}{N_b + \frac{N_p K_b X_p}{K_p X_b}}, \frac{bit_rate}{8 \times picture_rate} \right\}$$

here, T_i , T_p and T_b is the bits allocated to the I, P or B frame respectively[.]; N_i , N_p and N_b is the remained none coded I, P or B frames in the GOP respectively[.]; X_i , X_p and X_b is the global complexity estimation for the I, P or B frame respectively and is defined as the multiplier between coded bits and average quantization parameter for the frame[.];

bit_rate is the target bit rate[.], $picture_rate$ is the frame rate[.];

K_p and K_b are constants[.], K_p , K_b means the complexity ratio between P, B frame and I frame respectively[.];

R is the remained bits for the GOP, and after coding a picture it is updated as follows:

$$R = R - S_{i,p,b}$$

$S_{i,p,b}$ is the coded bits for the current frame.

Claim 5[.], (currently amended) The method of as claim 4 has said, wherein before coding a GOP, the remaining bits for the current GOP is initialized as follows:

$$R = G + R_{prev}$$

$$G = \text{bit_rate} \times N \div \text{picture_rate}$$

here, R is the remained bits for the current GOP[.];

N is the number of frames in the current GOP[.];

G is the number of bits for a GOP[.];

R_{prev} is the remained bits for the previous GOP[.], for the first GOP, $R_{prev}=0$.

Claim 6[.], (currently amended) The method of as claim 4 has said, wherein X_i , X_p and X_b are initialized as:

$$X_i = a \times \text{bit_rate}$$

$$X_p = b \times \text{bit_rate}$$

$$X_b = c \times \text{bit_rate}$$

here a , b and c are constants[.];

bit_rate is the target bitrate.

Claim 7. (canceled).

Claim 8[.], (currently amended) The method of as claim [7] 1 has said, wherein for motion estimation in P or B frame, the motion vector minimizing following expression is selected as the motion vector for the current macroblock:

$$J(m, \lambda_{MOTION}) = SA(T)D(s, c(m)) + \lambda_{MOTION} R(m - p)$$

here, $D(s, c(m))$ is used to evaluate the distortion from motion compensation[.];

$SA(T)D$ is the sum of the absolute difference after prediction (or after Hadamard transform) for the macroblock[.];

$R(m-p)$ is the bits used to code the motion vector[.];

s is the luma value of the current macroblock in the original frame[.];

c is the luma value in reference picture[.];

m is the motion vector[.];

p is the predicted motion vector[.];

λ_{MOTION} is the lagrangian constant and $\lambda_{MOTION} = \sqrt{\lambda_{MODE}}$ [.];

λ_{MODE} is the lagrangian constant.

Claim 9[[.]], (currently amended) The method of ~~as claim 2 has said,~~ wherein after the first rate distortion mode selection, the RDO based rate control further includes: calculating quantization parameter for the current macroblock[[.]]; ~~The~~ the quantization parameter is adjusted according to the macroblock activity and buffer status.

Claim 10[[.]], (currently amended) The method of ~~as claim 9 has said,~~ wherein the quantization parameter for the macroblock is adjusted according to the macroblock activity[[.]]; ~~After~~ after the first rate distortion mode selection, the sum of the absolute difference is used as the macroblock activity estimation[[.]]; ~~The~~ the macroblock activity is calculated as:

$$act_m = \sum_{i,j} |s(i,j) - c(i,j)| \quad N_act_m = \frac{(2 \times act_j) + avg_act}{act_j + (2 \times avg_act)}$$

here, i is the horizontal position of the pixel in the current macroblock[[.]]; j is the vertical position of the pixel in the current macroblock[[.]]; N_act_m is the activity of the current macroblock[[.]]; $s(i,j)$ is the luma value of the original pixel(i, j), $c(i, j)$ is the prediction value of pixel(i, j)[[.]]; avg_act is the average act_m in the previous coded picture which is coded with the same type as current picture[[.]]; act_m is the sum of the absolute difference after motion compensation or intra prediction.

Claim 11[[.]], (currently amended) The method of ~~as claim 9 has said,~~ wherein a virtual buffer is used to do rate control[[.]]; ~~First~~ first set up the mapping from the virtual buffer occupancy to macroblock quantization parameter, and the final macroblock quantization parameter is calculated as:

$$Q_m = \left(\frac{d_m^n \times 31}{r} \right) \times N_act_m$$

$$d_m^n = d_0^n + B_{m-1} - T_n \times (m-1) / MB_CNT$$

$$r = 2 \times bit_rate / picture_rate$$

here, Q_m is the quantization parameter of current macroblock[[.]]; d_m^n is the current buffer occupancy, and it equals d_m^I, d_m^P , and d_m^B for I, P, B frame respectively[[.]]; B_{m-1} is the bits used to code previous macroblock[[.]]; d_0^n is the initial buffer occupancy for current frame[[.]], n is i, p or b, corresponding to

d_0^i, d_0^p , and $d_0^b[[.]]$;

r is the size of virtual buffer.

Claim 12[[.]], (currently amended) ~~The method of claim 11, as Claim 11 said, wherein,~~
when coding the first frame, the virtual buffer occupancy is initialized with:

$$d_0^b = K_b \times d_0^i$$

$$d_0^i = 10 \times r / 31$$

$$d_0^p = K_p \times d_0^i$$

here r is the virtual buffer size; d_0^i, d_0^p , and d_0^b is the initial virtual buffer occupancy for i, p, or b frame[[.]]; K_p is the complexity ratio between I, P frame; K_b is the complexity ratio between I, B frame.

Claim 13[[.]], (currently amended) ~~The method of claim 12 as claim 2, 9, 10, 11 and 12 have said, wherein~~ the RDO based rate control also includes a second RDO mode selection, after calculating the final quantization parameter for the current macroblock[[.]]; ~~That is to say, thus~~ the selected quantization parameter for the current macroblock will be used to do RDO mode selection again[[.]]; ~~The~~ the mode which minimizes the following expression will be selected as the coding mode for the current macroblock:

$$D(s, c, MODE | QP) + \lambda_{MODE} R(s, c, MODE | QP)$$

here, s is the luma value of the original macroblock[[.]], c is the luma value of the reconstructed macroblock[[.]], λ_{MODE} is the lagrangian constant[[.]];

$$\text{For for I/P frame, } \lambda_{MODE} = 0.85 \times 2^{\frac{Q_{in}-1}{3}};$$

$$\text{For for B frame, } \lambda_{MODE} = 4 \times 0.85 \times 2^{\frac{Q_{in}-1}{3}} [[.]];$$

$D(s, c, MODE | QP)$ is used to evaluate the distortion of the current macroblock coded with mode $MODE[[.]]$;

$R(s, c, MODE | QP)$ is the bits used to code the macroblock with mode $MODE[[.]]$;

QP is the quantization parameter for the current macroblock.

Claim 14[[.]], (currently amended) ~~The method of~~ as claim 13 ~~has said, wherein~~ for motion estimation in P or B frame, the motion vector minimizing following expression is

selected for the current macroblock:

$$J(m, \lambda_{MOTION}) = SA(T)D(s, c(m)) + \lambda_{MOTION} R(m - p)$$

here, $D(s, c(m))$ is used to evaluate the distortion from motion compensation[.];

$SA(T)D$ is the sum of the absolute difference (or after Hadamard transform) for the macroblock[.];

$R(m-p)$ is the bits used to code the motion vector[.];

s is the luma value of the current macroblock in the original frame[.];

c is the luma value in reference picture[.];

m is the motion vector[.];

p is the predicted motion vector[.];

λ_{MOTION} is the lagrangian constant and $\lambda_{MOTION} = \sqrt{\lambda_{MODE}}$ [.];

λ_{MODE} is the lagrangian constant.

Claim 15[.], (currently amended) An apparatus for a rate distortion optimization (RDO) based rate control implementation includes following modules comprising: a video coding encoder module comprising a JVT processing module (for example, H.264 encoder module or JVT processing module), rate-distortion optimization a RDO mode selection and adaptive quantization module, a virtual buffer, and a global complexity estimation module;

wherein here, the JVT processing module receives the an input frame, and it is connected with the RDO mode selection and adaptive quantization module, the virtual buffer module and the global complexity estimation module[.];

the RDO mode selection module and adaptive quantization module is connected with the virtual buffer and the global complexity estimation module[.], it and is configured to receive receives the an input signal from the JVT processing module, and processes it to process the input signal based on the status of the virtual buffer module and the global complexity module status[.];

bit allocation for every picture in a GOP which includes an I frame, a P frame, or a B frame is conducted, a first rate distortion optimization mode selection for every macroblock in the current picture using a predicted quantization parameter based on the allocated bits is conducted, wherein the predicted quantization parameter is the quantization parameter of a previous macroblock, and a coding mode minimizing the following formula as the initial coding

mode for the current macroblock is selected;

$$D(s, c, MODE | QP) + \lambda_{MODE} R(s, c, MODE | QP)$$

where s is the luma value of the original macroblock, c is the luma value of the reconstructed macroblock, λ_{MODE} is the lagrangian constant;

$$\text{for I/P frame, } \lambda_{MODE} = 0.85 \times 2^{Q_{a-1}/3};$$

$$\text{for B frame, } \lambda_{MODE} = 4 \times 0.85 \times 2^{Q_{a-1}/3};$$

$D(s, c, MODE | QP)$ is used to evaluate the distortion of the current macroblock after it is coded with mode $MODE$;

$R(s, c, MODE | QP)$ is the bits used to code the macroblock with mode $MODE$;

QP is the quantization parameter for the current macroblock, and is equal to the predicted quantization parameter in the first rate distortion mode selection;

and the RDO mode selection and adaptive quantization module is configured to calculate a final quantization parameter for rate control using the information collected from the first rate distortion mode selection, and if the final quantization parameter is different from the predicted, execute a second rate distortion mode selection; and then calculate the quantization parameter for the macroblock.

In the last, the JVT processing module will is configured to output the final coded macroblock with the calculated parameter.

Claim 16[1,1]₂ (currently amended) The apparatus of as claim 15 has said, wherein before coding a GOP, does bit allocation for the pictures in the GOP with the average picture size is conducted[1,1]

Claim 17[1,1]₂ (currently amended) The apparatus of as claim 16 said, wherein the average picture size is calculated as:

$R/F = R \div F$, here, R is the target bit rate[1,1], F is the picture rate[1,1], R/F is the average picture size.

Claim 18[1,1]₂ (currently amended) The apparatus of claim 17 as claim 16 and 17 have said, wherein a does bit allocation adjustment in the GOP[1,1]is conducted, the The adjustment is shown as follows:

$$T_i = \max \left\{ \frac{R}{1 + \frac{N_p X_p}{K_p X_i} + \frac{N_b X_b}{K_b X_i}}, \frac{bit_rate}{8 \times picture_rate} \right\}$$

$$T_b = \max \left\{ \frac{R}{N_b + \frac{N_p K_b X_p}{K_p X_b}}, \frac{bit_rate}{8 \times picture_rate} \right\}$$

$$T_p = \max \left\{ \frac{R}{N_p + \frac{N_b K_p X_b}{K_b X_p}}, \frac{bit_rate}{8 \times picture_rate} \right\}$$

here, T_i , T_p and T_b is the bits allocated ~~the~~ to the I, P or B frame respectively[.]; N_i , N_p and N_b is the remained none coded I, P or B frames in the GOP respectively[.]; X_i , X_p and X_b is the global complexity estimation for the I, P or B frame respectively and is defined as the multiplier between the coded bits and average quantization parameter for the frame[.];

bit_rate is the target bit rate[.]; $picture_rate$ is the frame rate[.];

K_p and K_b are constants[.]; K_p , K_b means the complexity ratio between P,B frame and I frame respectively[.];

R is the remained bits for the GOP, and after coding a picture it is updated as follows:

$$R = R - S_{i,p,b}$$

$S_{i,p,b}$ is the coded bits for the current frame.

Claim 19[.], (currently amended) The apparatus of claim 18, ~~as Claim 18 has said,~~ wherein before coding a GOP, the remaining bits for the current GOP is initialized as follows:

$$R = G + R_{prev}$$

$$G = bit_rate \times N \div picture_rate$$

here, R is the remained bits for the current GOP[.];

N is the number of frames in current GOP[.];

G is the number of bits for a GOP[.];

R_{prev} is the remained bits for the previous GOP[.], ~~For~~ for the first GOP, $R_{prev}=0$.

Claim 20[.], (currently amended) The apparatus of ~~as claim 18 said,~~ wherein X_i , X_p and

X_b are initialized as:

$$X_r = a \times \text{bit_rate}$$

$$X_p = b \times \text{bit_rate}$$

$$X_b = c \times \text{bit_rate}$$

here a , b and c are constants[.];

bit_rate is the target bitrate.

Claim 21. (canceled).

Claim 22[.], (currently amended) The apparatus of claim 15, as claim 21 has said, wherein for motion estimation in P or B frame, the motion vector minimizing following expression is selected for the current macroblock:

$$J(m, \lambda_{\text{MOTION}}) = SA(T)D(s, c(m)) + \lambda_{\text{MOTION}} R(m - p)$$

here, $D(s, c(m))$ is used to evaluate the distortion from motion compensation[.];

$SA(T)$ is sum of the absolute difference (or after Hadamard transform) for the macroblock[.];

$R(m-p)$ is the bits used to code the motion vector[.];

s is the luma value of the current macroblock in the original frame[.];

c is the luma value in reference picture[.];

m is the motion vector[.];

p is the predicted motion vector[.];

λ_{MOTION} is the lagrangian constant and $\lambda_{\text{MOTION}} = \sqrt{\lambda_{\text{MODE}}}$ [.]

λ_{MODE} is the lagrangian constant.

Claim 23[.], (currently amended) The apparatus of as claim 22 has said, wherein after the first rate distortion mode selection, the rate control scheme further includes: Calculating calculating a new quantization parameter and adjusting it the new quantization parameter according to the macroblock activity and buffer status.

Claim 24[.], (currently amended) The apparatus of as claim 22 said, wherein for adjusting quantization parameter for the current macroblock[.], the sum of the absolute difference is used

as the macroblock activity estimation after first rate distortion mode selection[[.]], ~~and the~~ The macroblock activity is calculated as:

$$act_m = \sum_{i,j} |s(i,j) - c(i,j)| \quad N_act_m = \frac{(2 \times act_j) + avg_act}{act_j + (2 \times avg_act)}$$

here, i is the horizontal position of the pixel in the current macroblock[[.]], j is the vertical position of the pixel in the current macroblock[[.]], N_act_m is the activity of the current macroblock[[.]], $s(i,j)$ is the luma value of the original pixel(i,j), $c(i,j)$ is the prediction value of pixel(i,j)[[.]], avg_act is the average act_m in the previous coded picture which is coded with the same type as current picture[[.]], act_m is the sum of the absolute difference after motion compensation or intra prediction.

Claim 25[[.]], (currently amended) ~~The apparatus of~~ as claim 22 ~~has said, wherein the~~ [[a]] virtual buffer is used to do rate control[[.]]; ~~first~~ ~~First set~~ setting up the mapping from the virtual buffer occupancy to macroblock quantization parameter[[.]], ~~the~~ The macroblock quantization parameter is calculated as:

$$Q_m = \left(\frac{d_m^n \times 31}{r} \right) \times N_act_m$$

$$r = 2 \times bit_rate / picture_rate$$

$$d_m^n = d_0^n + B_{m-1} - T_n \times (m-1) / MB_CNT$$

here, Q_m is the quantization parameter of current macroblock[[.]]; d_m^n is the current buffer occupancy, and it equals d_m^I, d_m^P , and d_m^B for I, P, B frame respectively[[.]]; B_{m-1} is the bits used to code previous macroblock[[.]]; d_0^n is the initial buffer occupancy for current frame[[.]], n is i, p or b, corresponding to d_0^I, d_0^P , and d_0^B [[.]]; r is the size of virtual buffer occupancy.

Claim 26[[.]], (currently amended) ~~The apparatus of~~ as claim 25 ~~said, wherein~~ when coding the first frame, the virtual buffer occupancy is initialized with:

$$d_0^i = 10 \times r / 31$$

$$d_0^p = K_p \times d_0^i$$

$$d_0^b = K_b \times d_0^i$$

here r is the virtual buffer size; d_0^i, d_0^p , and d_0^b is the initial virtual buffer occupancy for i, p, or b frame[.]; K_p is the complexity ratio between I, P frame; K_b is the complexity ratio between I, B frame.

Claim 27[.], (currently amended) The apparatus of as claim 23, ~~24, 25, 26 have said,~~ wherein the RDO based rate control also includes a second RDO mode selection, after quantization parameter decision for the current macroblock[.], ~~That is to say,~~ thus the decided quantization parameter for the current macroblock will be used to do RDO mode selection again[.]; ~~The~~ the mode which minimizes the following expression will be selected as coding mode for the current macroblock:

$$D(s, c, MODE | QP) + \lambda_{MODE} R(s, c, MODE | QP)$$

here, s is the luma value of the original macroblock[.], c is the luma value of the reconstructed macroblock[.], λ_{MODE} is the lagrangian constant[.];

$$\text{for For IP frame, } \lambda_{MODE} = 0.85 \times 2^{\frac{qp-1}{3}};$$

$$\text{for For B frame, } \lambda_{MODE} = 4 \times 0.85 \times 2^{\frac{qp-1}{3}} [.] ;$$

$D(s, c, MODE | QP)$ is used to evaluate the distortion of the current macroblock after it is coded[.];

$R(s, c, MODE | QP)$ is the bits used to code the macroblock with mode $MODE$ [.];

QP is the quantization parameter for current macroblock.

Claim 28[.], (currently amended) The apparatus of as claim 27 said, wherein for motion estimation in P or B frame, the motion vectors minimizes following expression are selected as the motion vectors for the current macroblock:

$$J(m, \lambda_{MOTION}) = SA(T)D(s, c(m)) + \lambda_{MOTION} R(m - p)$$

here, $D(s, c(m))$ is used to evaluate the distortion from motion compensation[.];

$SA(T)D$ is sum of the absolute difference (or after Hadamard transform) for the macroblock[.];

$R(m-p)$ is the bits used to code the motion vector[.];

s is the luma value of the current macroblock in the original frame[.];

c is the luma value in reference picture[.];

m is the motion vector[.];

p is the predicted motion vector[.];

λ_{MOTION} is the lagrangian constant and $\lambda_{MOTION} = \sqrt{\lambda_{MODE}}$ [.];

λ_{MODE} is the lagrangian constant.

Claim 29[.], (currently amended) The apparatus of claim 28, as Claim 28 said, wherein quantization parameter from the RDO mode selection and adaptive quantization module is sent back to the JVT processing module, the macroblock is coded by the JVT processing module and output of the JVT processing module.